Corrosion of Steel in Concrete

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The voice of the concrete repair and refurbishment industry
How?

• Anodes and Cathodes
• Anode loses Metal
• Cathode reacts with oxygen and water
• El in the Electrolyte
How?

Salt Solution

ZINC

COPPER
Are you sure?
Steel in Concrete

• Passive Film Protects
• But....
  – Chlorides
  – Carbonation
• Steel Rusts
  – Lose reinforcement
• Rust is bigger than steel
• Bits fall off
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Steel in Concrete - Chlorides

Repaired CATHODE

SALTY and ANODIC
So Is it Rusting?

• Can you see any rust?

– Visual Inspection

• Testing

– Carbonation, Chlorides, Cover

– Half-cell potentials

• Measure voltages,

• Need to think about results

– Delamination

• On the surface or at depth
Carbonation

- Expose fresh concrete
- Spray on phenolphthalein
- Measure depth of pink
Chlorides

• Find steel
• Miss steel
• Drill hole
• Ignore first 5mm
• Collect dust at depth increments
• Send off for analysis
• Dust can be used for
• Cement content
• Sulphates
Cover

- Sweep meter around, record lowest reading
- Hilti Ferroscan
  - Logs as it goes
  - Large amounts of data can be used to indicate bar sizes, spacing and variability
  - Has its limits
Half-cell

- Measures voltages and currents
- Guidance available on meanings, but take care
- Upside down half cells
- Galvanised metal
- 600mV not necessarily worse than 500mV

- Looking for higher or lower
- Don't always need to connect to steel
Hammer survey

• Hit with small hammer
• Record where it thunks
• Sometimes it thunks when it's solid
• Sometimes it doesn't thunk when it's loose
Cathodic Protection

- Using CP stops rust in any environment
- Chloride contaminated concrete can remain

- Saves
  - Propping
  - Access
  - Materials
  - Carbon

- Impressed Current or Galvanic
Cathodic Protection

\[ \frac{1}{2} O_2 + H_2O + 2e^- \text{(metal)} \rightarrow 2OH^- \text{(aq.)} \]

Fe (metal) \[ \rightarrow \] Fe\(^{2+} \] + 2e\(^-\)

\[ +ve \]

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Documents

• BS EN ISO 12696 2012 - CP of concrete
  – Includes criteria, first published in 2000
• BS EN 15257 2006 – Certification of CP people
• BA 83 – Highways Agency Advice Note
• TR 73 – Concrete Society Guidance
Hydrogen Embrittlement

• BS EN 12696:
  – -720mV vs Silver / Silver Chloride / 0.5M Potassium Chloride
• Or
  – 100mV Decay in 24 hours
• Or
  – 150mV decay over longer periods
• AND
• No potentials more negative than -900mV for prestressed concrete
Prestressed beams

- Prestressed concrete now getting around the age
- "Improved QA"
- Risk of Hydrogen Embrittlement

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Hydrogen Embrittlement

- If steel is >600MPa UTS
- AND
  - Is under high stress
- AND
  - Is susceptible to it
- AND
  - Hydrogen is being generated
- Risk of hydrogen embrittlement
Hydrogen Embrittlement

• Most cases are self corrosion in very high strength steels
• Simple to avoid in most reinforced concrete
  – Don’t turn the system up that high
• We rarely achieve the -720mV
• All the systems I have designed, commissioned or monitored have never come close to -900mV
• Use Galvanics if you’re not sure
Summary

• Steel rusts
• Inspection needs care
• For chloride induced corrosion CP saves
  – Carbon Dioxide
  – Repairs
  – Access
  – Propping
• Codes are available
  – Competence of personnel
  – Safe Operation of Systems
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